Roving in the Permanently Shadowed Regions of Planetary Bodies

Completed Technology Project (2014 - 2018)

Project Introduction

The existence of volatiles in the polar regions of airless planets has recently been verified by the LCROSS and Messenger missions. These polar volatiles are dry ices of water, methane, and ammonia. After processing, it is possible to breathe, drink, burn, fuel, and create with these volatiles. The production of resources external to Earth will allow for space vehicles and outposts to utilize the local resources of a planet to supply space exploration missions, rather than being dependent on resources launched from Earth. The majority of the volatiles on the Moon and Mercury exist in or near the permanently shaded craters at the polar regions. Existing rover technologies are incapable of the types of perception, navigation, and planning required by the challenges of a dark environment that restrict the rover's ability to perceive its surroundings, tread upon cryogenic regolith, tolerate communication interruptions, and overcome inherent uncertainty. Due to these technical challenges, rover missions have not yet operated at polar latitudes. Innovative technologies to address these challenges are essential for exploring for volatiles and operating in these polar regions. The proposed technology, for instance, could enable NASA's 2018 RESOLVE mission to explore polar volatiles. Operations in illuminated and benign climates are well understood. This research proposes to examine and produce novel methods for sensing, mapping, and localization in and around the permanently dark regions of planetary bodies. The research will enable the exploration of previously inaccessible dark environments including pits, cold traps, and subterranean voids such as lava tubes and caves on the Moon and Mars. This research will additionally have impacts on the operation of robots at night, in subterranean cavities, and other dark environments. The proposed research will allow robots to perceive their surroundings in the absence of sunlight by developing innovative methods in passive sensing, computational imaging, and active lighting. The approach is to build a better representation of the scene by capturing and combining multiple images of the same scene while modulating the imaging parameters (e.g. lighting, focus, exposure, etc.). The produced images can then be transformed and used with digital elevation maps, pre-existing multi-spectral orbital imagery, and simultaneous localization and mapping methods to map the robot's terrain and iteratively estimate its position in the dark. The research will develop methods of sensor fusion and domain considerations to enhance the rover's perception abilities and build high-resolution 3D models of the rover's environment with graphical models like Markov Random Fields and Belief Propagation. Sensing methods will be characterized and evaluated on artificial and analog terrains under planetary lighting conditions. Comparative studies will be performed to determine the optimal sensors and possible areas of novel development. Localization and mapping algorithms will then be developed and tested with simulated data on pre-existing data derived from the Lunar and Mars Reconnaissance Orbiters. Small scale testing will then be conducted in analog terrain under relevant lighting conditions and by collecting overhead imagery. Once the methods have been validated in simulation and small scale testing they will be field-tested in several relevant environments

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including subterranean mines and outdoor sites during darkness.

Anticipated Benefits

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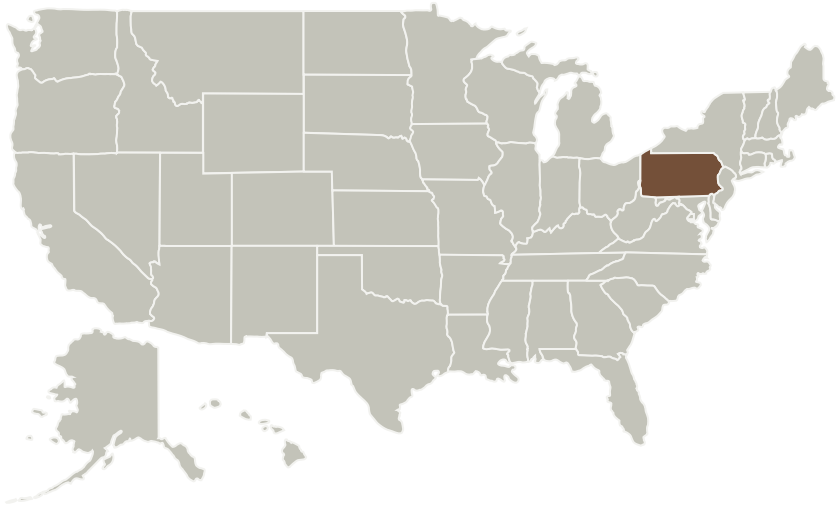
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Carnegie Mellon University	Lead Organization	Academia	Pittsburgh, Pennsylvania

Primary U.S. Work Locations
Pennsylvania

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Carnegie Mellon University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

William (red) Whittaker

Co-Investigator:

Joseph Bartels

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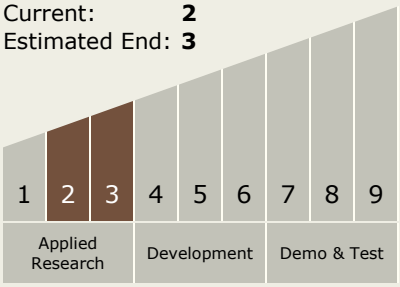
Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX07 Exploration Destination Systems
  - TX07.1 In-Situ Resource Utilization
    - TX07.1.1 Destination Reconnaissance and Resource Assessment

Target Destinations

The Moon, Mars, Others Inside the Solar System